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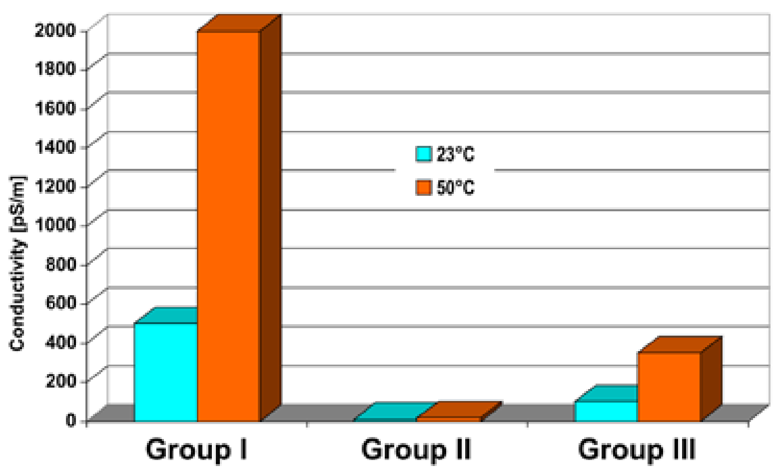
New problems, new solutions

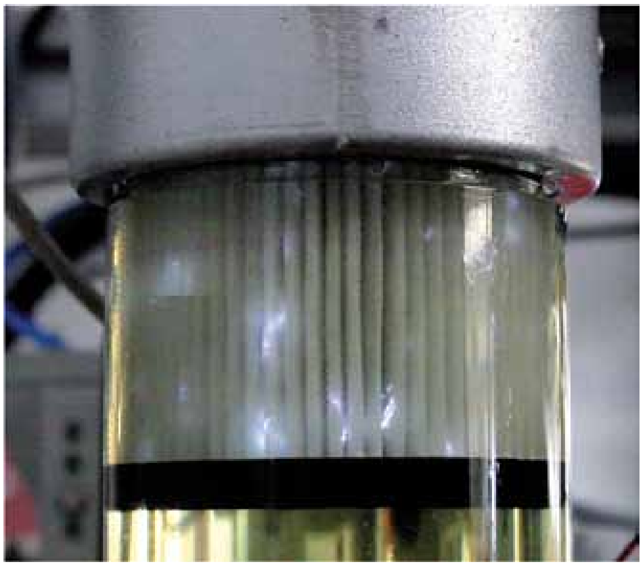
Today’s environmentally-friendly hydraulic fluids can cause serious problems that did not occur with fluids containing heavy-metal additives. Electrostatic discharges and a host of other detrimental effects can occur, but solutions exist to alleviate the problems.

Hydraulic fluid producers introduce additives (usually several, as an additive package) into base oils to give them the characteristics they need for the demanding conditions of hydraulic systems. Additives improve viscosity, reduce friction, prevent wear, and allow the fluid to tolerate high temperatures without oxidizing. Group I base oils contain aromatics, most of which are toxic, and zinc, a heavy metal that promotes wear resistance. Because of their toxicity and potential threat to environmental systems, they no longer comply with current international environmental standards.

Hydraulic and lubrication oils in Group II to IV are produced with appropriate additive packages, so they contain no toxins or carcinogens, are free of heavy metals, and are ashless, meaning they produce no residue as a result of combustion. However, because they do not contain any metal, these fluids have low electrical conductivity, Figure 1. If this oil flows through the filters in the hydraulic system, an electrostatic charge is generated. This can result in sparking, Figure 2, which can cause explosions in the reservoir or damage hydraulic components, such as valves and filters. The sparks can also can also interfere with or damage electronic components, and form oil-aging deposits.



Group 1 fluids contain zinc and other heavy metals, which gives them much higher electrical conductivity than Group II and III fluids, which are environmentally acceptable.



Lab studies at HYDAC, left, reveal that the absence of heavy metals in today's environmentally compatible hydraulic fluids allow electrostatic charges to build up. The resultant electrostatic discharges in a filter element, above, rapidly age the hydraulic oil, leading to the formation of varnish.

When modern zinc-free and ashless oils age, very fine (less than 1 µm) solid contamination is formed that does not dissolve in the oil and is commonly referred to as varnish. This varnish settles on the oily surfaces of the components and has a detrimental effect on their function. Potential consequences include seized valve spools, overheated solenoids, and extremely short filter element service life.

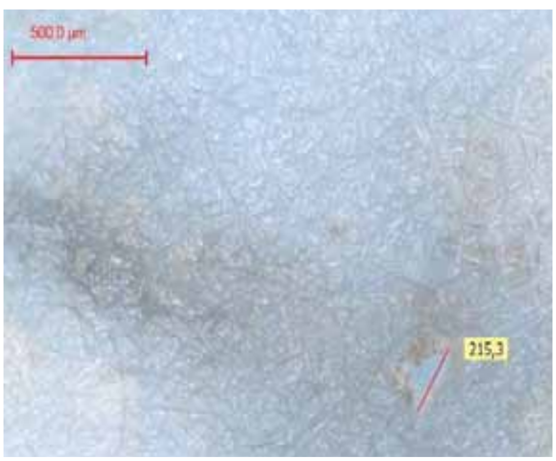
Electrostatic discharges

If two substances (such as filter media and hydraulic fluid) with different electron work functions are brought together, electrons at the point of interface are transferred from the material with lower work function to the material with a higher work function. An electron deficit exists at the interface, and a diffusion layer in the fluid forms that has a charge opposite that of the filter media. The charge of this layer weakens with increasing distance from the filter media.

When the fluid is flowing, the charge is carried downstream and creates a difference in voltage. The faster the fluid flow, the higher the voltage. If the voltage exceeds a threshold value, a sudden equalization of voltage will occur, usually in the form of sparking. However, the fluid must have low conductivity for sparking to occur. Otherwise, the charges in the diffuse layer can flow back and be equalized. This is what happens with fluids containing heavy metal additives.

Consequences — The consequences of electrostatic discharges can be serious. For example, when the charge is carried farther downstream by the oil, uncontrolled discharges can occur in the hydraulic reservoir. Depending on the oil-air mixture in the reservoir, explosions can occur. In addition, holes may be burned into the filter media as a result of sparking.

Figure 5 shows a hole about 200 µm in diameter in 3 µm filter media. The hole creates a path for contaminants to pass through the filter, severely compromising the filter's effectiveness. Other components in the system, such as coolers and valves, can also be damaged by uncontrolled discharges.



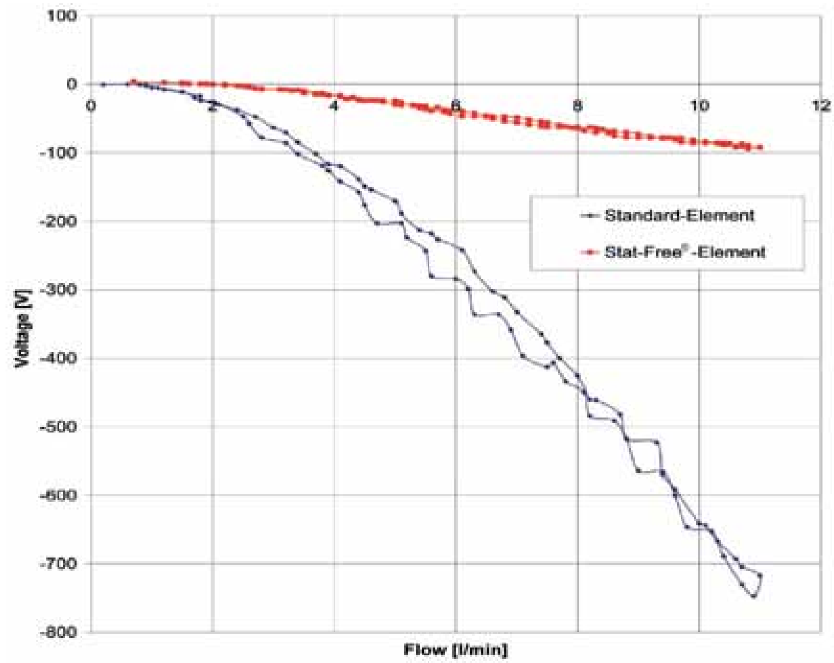
Electrostatic discharges can not only accelerate aging of hydraulic fluid, but burn holes in filter media as well. Here, a hole more than 200 µm in diameter negates the effectiveness of the 3-µm media it has compromised.

This test bench at HYDAC was designed and built specifically for analyzing the electrostatic behavior of hydraulic filters. It proved essential in the development of Stat-Free elements, which combat static buildup and dissipate charges that do occur.

The electrostatic discharges can also cause electromagnetic waves that disrupt and damage sensitive sensors and electronic components. Not only do the discharges damage the hydraulic components, but the hydraulic oil itself. The sparking breaks molecular bonds of the fluid, forming free radicals that polymerize into long chains. This, in turn, leads to the formation of varnish accelerating oil aging.

Solution — With the help of a custom designed test bench, Figure 6, HYDAC Filtertechnik engineers have analyzed the electrostatic behavior of hydraulic filters in critical oils. The result is HYDAC's Stat-Free filter element series, which combats the problem of electrostatic discharge. The elements are designed to be discharge-capable and are made of media combinations that minimize the charge generation of the filter and the oil, Figure 7. Stat-Free elements not only eliminate the consequences of electrostatic charging, but the cause itself.

A purely discharge-capable design without modifying the media reduces sparking in the element, but the oil continues to be charged. The charges at the interface of the



This graph shows that standard hydraulic filter elements do little to dissipate electrostatic charges. Stat-Free elements, however, tolerate electrostatic discharges and prevent their buildup.

This filter-breather from a large hydraulic system shows evidence of being burned by electrostatic discharges. Tests showed static charges of up to 17,000 V. After retrofitting the reservoir with Stat-Free elements, no electrostatic discharges were detected, and electrostatic charges were measured at 3 V or less.

filter can dissipate, but the fluid has an even higher charge because no sparking occurs on the filter to neutralize the charge. The charged oil is carried downstream and uncontrolled discharges are possible in other parts of the system. Under certain circumstances, this can lead to serious damage, such as an explosion in the reservoir.

HYDAC also developed its StatStick sensors, which measure voltage in the oil downstream of the filter to allow application engineers to carry out field measurements. For example, HYDAC engineers learned of possible explosions in the hydraulic reservoir of a large hydraulic system after breather filters were completely burned out, Figure 9. The filters were not optimized for electrostatic charging. Measurements were taken using the StatStick, which revealed voltage peaks to 17,000 V and dangerous discharge sparks in the tank. Once retrofitted with Stat-Free elements, no further discharges could be detected and the voltage dropped to 3 V or less.

Varnish

Varnish is the product of chemical reactions in the oil, often called oil aging. Aging accelerates significantly in the presence of local hot spots (greater than 300° C) in the oil. Electrostatic discharges are often a source of such high temperatures. Other hot spots can be caused by micro-dieseling or hot components. The result of oil aging in these cases is always the same. Hydrocarbon chains of the base oil are essentially broken apart by high local temperatures. The chain sections react with other hydrocarbons, oil additives, or oxygen and eventually form varnish, which is deposited as oil sludge in the system.

Modern oils in Groups II to IV contain numerous additives that improve the base oil's characteristics, such as viscosity index, corrosion protection, foaming tendency, adhesion characteristics, and oil aging behavior (antioxidants). Oil aging behavior is affected mainly by two substances in the additive package: phenols and amines. These two substances act as radical scavengers and interrupt the chemical reaction that would otherwise result in varnish. In doing this, however, the radical scavengers become depleted. If they are exhausted, oil aging progresses rapidly.

The level of amines and phenols reveals the aging condition of the oil, but it cannot be detected using traditional measuring methods. New measuring methods, such as the RULER (Remaining Useful Life Evaluation Routine) test or the MPC (Membrane Patch Colorimetry) test, are required to establish the aging condition of the oil. The RULER test compares the level of antioxidants in a sample of used oil to that of fresh oil so that the maximum remaining life of the used oil can determined.

Consequences — The consequences of varnish buildup from rapid aging vary depending on where the deposits form. For example, deposits in the reservoir may pose no immediate threat, but can impede operation of downstream components. However, varnish in valves can cause spools to stick, leading to operational malfunctions and premature component failures. In addition, varnish is an insoluble soft substance, which can clog hydraulic filters, often within a few hours. If the level of antioxidants is below 60% to 80%, a complete oil change should be performed.

Solution — If these or other acute problems with varnish exist in a hydraulic system, specialized filters can be specified to help alleviate problems. HYDAC's IXU is an example. In contrast to standard hydraulic filters, the principle behind this filter is chemical, not mechanical. The oil flows through a resin that absorbs oil aging products, effectively removing them from the system.

However, these filters treat the symptoms, not the cause— the formation of oil aging products. Stat-Free filter elements can be used to combat rapid oil aging. The electrostatically optimized elements prevent discharges in the oil to prevent formation of oil aging products. Also, depending on the system, lowering the hydraulic oil's temperature can significantly reduce oil aging.

To prevent the oil condition from deteriorating, regular oil sample analysis should be performed. Combining sample analysis with permanent oil monitoring is even more effective by providing an accurate assessment of the oil's condition.

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